A. G. Contract No. KR97 1750TRN
ADOT ECS File: JPA 97-120
Project: SRP #466/R0466 10P
Scope: Develop Variable Speed Limit Fuzzy Logic Algorithm

AGREEMENT
BETWEEN
THE STATE OF ARIZONA
AND
THE ARIZONA BOARD OF REGENTS
ACTING FOR AND ON BEHALF OF
NORTHERN ARIZONA UNIVERSITY

THIS AGREEMENT is entered into 15 AUGUST, 1997, between agencies of the STATE OF ARIZONA, to wit; the DEPARTMENT OF TRANSPORTATION (the "DOT") and the ARIZONA BOARD OF REGENTS acting for and on behalf of the NORTHERN ARIZONA UNIVERSITY (NAU), (the "University").

I. RECITALS

1. The DOT is empowered by Arizona Revised Statutes Section 28-108 to enter into this agreement and has by resolution, a copy of which is attached hereto and made a part hereof, resolved to enter into this agreement and has delegated to the undersigned the authority to execute this agreement on behalf of the DOT.

2. The University is empowered by Arizona Revised Statutes Section 15-1626 to enter into this agreement and has by Policy BOR 3-103, a copy of which is attached hereto and made a part hereof, authority to execute this agreement on behalf of the University.

3. The DOT and the University desire to conduct research and achieve the development of a "fuzzy logic" algorithm for variable speed limit display signs for State highways, at an estimated cost of $97,600.00, all at DOT expense, hereinafter referred to as the Project.

THEREFORE, in consideration of the mutual agreements expressed herein, it is agreed as follows:

II. SCOPE OF WORK

1. The DOT will:

a. Appoint a Project coordinator within the DOT's Transportation Technology Group to interface with the University relating to the research and development.

b. Provide the University with information and data as may be reasonably available to assist in the Project research and development.

c. Reimburse the University within forty-five (45) days after receipt and approval of monthly invoices, in a total amount not to exceed $97,600.00.

2. The University will:

a. Appoint a Project coordinator at the University (NAU) to interface with the DOT relating to the research and development.

b. Accomplish the research and development generally in accordance with Exhibit A, which is attached hereto and made a part hereof, including the development of a "fuzzy logic" algorithm, simulation testing, the construction and testing of a prototype, and a final report documenting the program, data derived, and the final results. Such reports will be in a format compliant with the DOTs "Guidelines for Preparing Research Reports."

c. No more often than monthly, invoice the DOT in the form of Exhibit B attached hereto, supported by narrative reports and an accounting of monthly costs and expenditures on the Project. Upon completion of the Project, provide the DOT with a detailed final report.

III. MISCELLANEOUS PROVISIONS

1. Title to all documents, reports and other deliverables prepared by the University in performance of this agreement shall rest jointly with the DOT and the University.

2. This agreement shall become effective upon signature by the parties hereto, and shall remain in force and effect from 15 August 1997 until completion of said Project and reimbursements; provided, however, that this agreement, may be cancelled at any time prior to the commencement of performance under this agreement, upon thirty (30) days written notice to the other party.

3. The parties agree to comply with all applicable state and federal laws, rules, regulations and executive orders governing equal employment opportunity, immigration, nondiscrimination and affirmative action.

4. This agreement may be cancelled in accordance with Arizona Revised Statutes Section 38-511.

5. The provisions of Arizona Revised Statutes Section 35-214 are applicable to this contract.

6. In the event of any controversy which may arise out of this agreement, the parties hereto agree to abide by required arbitration as is set forth in Arizona Revised Statutes Section 12-1518 and 12-133 and rules promulgated thereunder.

7. All notices or demands upon any party to this agreement shall be in writing and shall be delivered in person or sent by mail addressed as follows:

Arizona Department of Transportation
Joint Project Administration
205 South 17 Avenue, Mail Drop 616E
Phoenix, AZ 85007

Northern Arizona University
Office of Grant and Contract Services
NAU Box 4130
Flagstaff, AZ 86011-4130

IN WITNESS WHEREOF, the parties have executed this agreement the day and year first above written.

STATE OF ARIZONA

NORTHERN ARIZONA UNIVERSITY

By ____________________
KATHRYN CRUZ-URIBE
Interim Associate Provost
for Research and Graduate Studies

DEPARTMENT OF TRANSPORTATION

By ____________________
TIM WOLFE
Assistant State Engineer

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JPA 97-120

RESOLUTION

BE IT RESOLVED on this 5th day of August 1997, that I, the undersigned LARRY S. BONINE, as Director of the Arizona Department of Transportation, have determined that it is in the best interests of the State of Arizona that the Department of Transportation, acting by and through the Intermodal Transportation Division, to enter into an agreement with Northern Arizona University for the purpose of defining responsibilities for the University to conduct research and develop a "fuzzy logic" algorithm for implementing a variable speed limit control system.

Therefore, authorization is hereby granted to draft said agreement which, upon completion, shall be submitted to the Assistant State Engineer for approval and execution.

Dallis B Saxton

for LARRY S. BONINE
Director

APPROVAL OF

THE NORTHERN ARIZONA UNIVERSITY ATTORNEY

I have reviewed the above referenced proposed intergovernmental agreement, between the DEPARTMENT OF TRANSPORTATION, HIGHWAYS DIVISION, and the NORTHERN ARIZONA UNIVERSITY, and declare this agreement to be in proper form and within the powers and authority granted to the University under the laws of the State of Arizona.

DATED this 20 day of August, 1997.

A. Dean Pickett

Attorney

White Paper on a Fuzzy Variable Speed Limit Device

2/3/97

John Placer and Assim Sagahyroon
Department of Computer Science and Electrical Engineering
Northern Arizona University

John Harper and Joshua Sarath
Arizona Department of Transportation

This paper describes an approach for the application of fuzzy control systems technology to the development of a variable speed limit device for improving driving safety on Arizona highways. This approach would be a significant improvement on prior solutions for the following reasons.

1. Fuzzy technology is a good match when dealing with complex nonlinear systems that involve multiple input and output parameters. A variable speed limit device would involve multiple inputs from sensors monitoring weather conditions and potentially from traffic monitoring sensors. Multiple outputs would also be needed which would include speed limit updates and signals to preprogrammed message boards.
2. Fuzzy technology is a powerful way in which to solve problems when imprecision and vagueness are inherent aspects of the problem domain. Road safety conditions do not change at precise values of environmental parameters such as road ice thickness and wind velocity. Rather imprecise ranges of such parameters are best used to determine safe speed limits and other safety issues
3. The fuzzy system design process involves close interaction with experts in the problem domain. In the case of the development of an intelligent traffic system, those persons most qualified to assess the safety issues (i.e the Arizona Department of Public Safety, highway maintenance personnel, ADOT engineers, etc.) would be intimately involved in the design effort.
4. Fuzzy control systems make use of linguistic rules that can be read and understood by engineers and non-engineers alike. The rules that form the heart of a fuzzy control system are written in everyday linguistic terms provided by the domain experts themselves. This allows these same experts not only to actively participate in the design process but also to participate in the review and testing process.

Background

The public and their elected officials know that transportation is one of the elements of our national infrastructure used by virtually every American, everyday. They now recognize that our current transportation system is in need of significant improvements. Age old approaches to solving transportation problems no longer work. We need new, fresh ideas and approaches; innovative solutions are needed.

In 1991, Congress authorized a program exploring the use of advanced computer and sensor technologies to improve the safety and efficiency of travel on highways and mass transit. That program has evolved to become known as Intelligent Transportation Systems (ITS). In establishing the ITS program, Congress laid out a set of diverse objectives. These included reducing congestion, making travel safer, increasing productivity and safeguarding the environment. These objectives are to be achieved through the use of advanced technologies which include information processing, communications, control and electronics. The objectives of the ITS program, therefore, can be realized by involving research, strategic planning and operational tests of new technologies and systems.

Traffic accidents and congestion take a heavy toll in lives, lost productivity and wasted energy. In 1993, traffic accidents claimed 40, 115 lives and injured an additional 3 million people. Cited in many of these accidents were 'speed too fast for conditions.' The *Strategic Plan for Early Deployment of Intelligent Transportation Systems on Interstate 40 Corridor* identified several 'high priority needs that must be addressed.' One of those high priority needs was ' Variable speed limit signing based on weather conditions.' The Arizona Department of Public Safety (DPS) has also identified variable speed limits as a major issue. On a national and worldwide basis, countries and communities are interested in finding ways to control speeds based on actual roadway and environmental conditions.

Trying to determine an appropriate driving speed under less than ideal conditions is a difficult challenge at best. Equally difficult is for law enforcement agencies to enforce and cite someone going too fast for conditions. It is a difficult and subjective determination. In many cases drivers are cited for going too fast for conditions, after the accident has occurred. It's a difficult and subjective determination. Currently no system is available to identify safe speed limits on a variable basis. Attempts have been made to implement such systems, such as one recently tested in Albuquerque, New Mexico, but most have been viewed as failures. The Washington Department of Transportation is testing a variable speed limit signing system in their state on the Interstate 94 corridor. Many countries in Europe have also undertaken testing. Many, if not all, of these projects utilize similar technologies and methodology.

Travelers have relied upon control systems, such as the traffic signal, that have changed little since they were first developed. The same can be said of speed limits in general. In most jurisdictions, maximum speed limits are posted based on ideal conditions. Generally this has little to do with actual environmental or roadway conditions. Similarly, systems have been developed to control speeds based on conditions that may not reflect driver behavior or actual conditions. This breeds disrespect and eventual disregard for the message. What is needed is a real time, environmentally accurate and responsive system that displays to motorists, safe driving speeds. The system proposed for this research project, utilizing newly developed concepts in fuzzy control systems, will take a different, innovative approach to this issue.

Fuzzy Technology

Fuzzy systems are well suited to the control of complex non-linear systems where classical mathematical analysis is difficult and imprecision is an inherent part of the problem domain. Fuzzy systems currently are being used in numerous and diverse applications. Consumer products now utilize fuzzy control systems in washing machines, air conditioners, video recorder controls, television controls, vacuum cleaners, microwave ovens, and in auto-focus mechanisms in cameras. Some of the industrial, engineering, and scientific applications of fuzzy systems include water purification, nuclear reactor control, elevator control, autonomous orbital operations, aircraft flight control, and gasoline refinery catalytic reformer controls. In short, fuzzy technology is proving itself to be effective in a broad cross section of difficult control problems. It is now time to apply this powerful technology to Intelligent Transportation Systems.

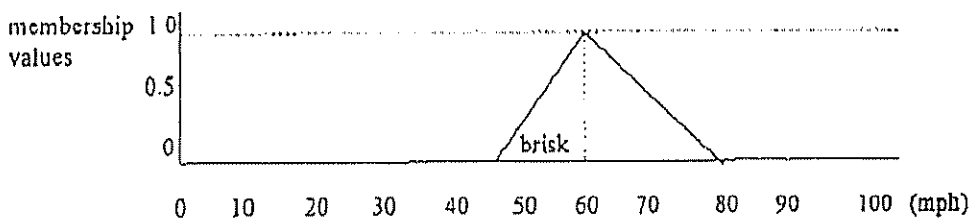
At the heart of a fuzzy control system is a collection of conditional statements that make use of everyday linguistic terms. For example, the following rule might be one of a number of rules found in a fuzzy system that relates water levels and wind velocity to a resulting speed limit.

If water_level is high and wind_velocity is brisk then driving_speed is low.

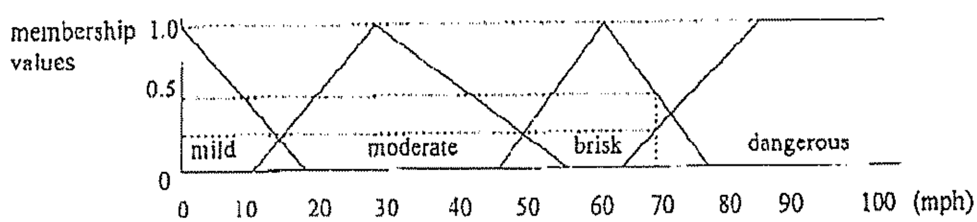
In the sample rule given above, water_level and wind_velocity represent measured quantities or input values that are being monitored by our hypothetical fuzzy system whereas the entity driving_speed represents an output variable that is being controlled by the system. Thus, if the water level input sensor measures a *high* water level and the wind velocity input sensor measures a *brisk* wind velocity, then the variable speed limit device being controlled by our hypothetical system is made to broadcast a *low* driving speed. The entities *high, brisk,* and *low,* are called linguistic terms and are used to represent imprecise or vague concepts.

Working with imprecision can actually be used to advantage when solving problems such as determining a safe driving speed based on subjective measurements. To understand this advantage consider the consequences of treating the wind velocity *brisk* as a precise category or set of values. First one would have to determine the exact range of velocities that are to be classified as brisk. If one decided that the low end of this range was 50 mph, then a wind velocity of 49.9999 mph would not be considered to be brisk whereas a wind velocity of 50.0000 mph would be considered a brisk velocity. Similarly if one decided that the high end of the set of brisk velocities was 75 mph, then a wind velocity of 75.0001 mph would not be considered to be brisk whereas a wind velocity of 75.0000 would be regarded as a brisk velocity. Both of these precise limits do not relate well to the way in which a category like *brisk* is used in everyday life. A small change in wind velocity should not result in a large and abrupt change in how the new velocity is conceptualized. Such an abrupt transition occurs only when brisk is assumed to be a precise concept because then any given wind velocity must be classified as belonging to the set *brisk* either completely or not at all. In other words, without imprecision the boundaries of categories are abrupt and precise.

To remedy this situation, the boundaries of the set *brisk* can be made "fuzzy" or imprecise by allowing wind velocities to belong to the set with partial membership. An example of this fuzzification of the set *brisk* is given below.



In the graph above, only the velocity 60 mph belongs completely to the set *brisk* since its membership value is 1.0. All other velocities roughly between 45 and 80 mph belong to the set with membership values somewhere between 0.0 and 1.0. For example, 55 mph has a membership value of approximately 0.7 in the set *brisk*. In other words, it can be said that 55 mph has the attribute of briskness to degree 0.7 whereas 60 mph has 100% of the attribute of briskness. When other categories of wind velocity are added to the graph above, it can be seen that making our sets fuzzy or imprecise allows wind velocities to belong to more than one set. For example, in the graph given below 70 mph belongs to the set of *brisk* velocities to about degree 0.5 and it also belongs to the set of *dangerous* velocities to roughly degree 0.25. Thus 70 mph is considered both a brisk and a dangerous velocity although it is more brisk than dangerous. This overlapping of conceptual categories is compatible with the way humans think about the world and it also results in control systems whose output characteristics move smoothly from one category of input value to the next.

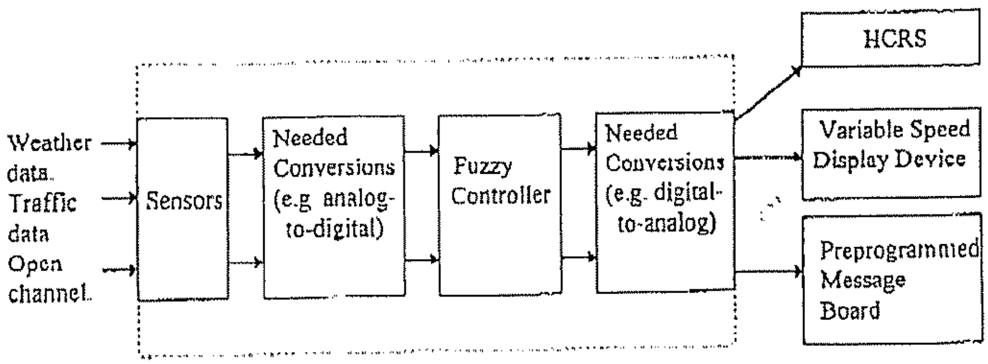


It is important to point out that the use of linguistic terms like *high, brisk*, and *low*, in a fuzzy system's rule set, allows that rule set to be read and understood by persons with and without extensive technical training. The rules offer an intuitive view of how the corresponding fuzzy control system operates. In fact this intuitive approach to modeling a control problem has many advantages. One major advantage relates to the development of the fuzzy control algorithm (rule set). A fuzzy system can be effectively developed by working closely with experts in a field of interest. The knowledge of these experts is directly encoded in a simple set of conditional statements that use linguistic terms and categories utilized by the experts themselves. The rules then reflect the manner in which the experts think and reason about their field of expertise. Even though these experts are not trained as fuzzy engineers, they can actively participate in the development of the fuzzy control algorithm that solves the problem of interest. In addition to this, they also can easily review the rules at each stage of development in order to eliminate inaccuracies or misunderstandings early in the design process.

The development of a fuzzy control algorithm for a variable speed limit device would involve close interaction with police officers, highway maintenance workers, ADOT engineers, and other related personnel. The experience and knowledge of these experts would be directly encoded into the fuzzy control system developed for the variable speed limit device. This same pool of experts would be used to review the rules developed in order to provide feedback on the overall conceptual fitness of the rule set. Of course, the final implementation and simulation testing of the system would be conducted by the engineers responsible for creating the system. However, the simulated system could be made available to the real "experts" so that they could also be involved in testing the system by comparing their intuitive notion of what the input-output relationships should be with the actual performance of the simulated system.

Design Concept

The fuzzy variable speed limit system being proposed would contain multiple inputs and at least two outputs. The inputs would be made up of various types of sensor data such as wind velocities, road ice thickness, road water levels and other weather related information. Other inputs might include traffic information such as traffic flow density data and traffic speed data. The output of the proposed fuzzy system would include a variable speed limit rating as well as a signal to be broadcast to a preprogrammed traffic message board. A simple block diagram is given below.



In the diagram above, an open channel has also been suggested. This channel could be used by police or ADOT to send a signal to the fuzzy controller. This signal might be used to override all other inputs in the case of an accident or other emergency situation.

Development Plan

Develop Fuzzy Algorithm (August 1997 - December 1997)

Development of the fuzzy control algorithm, the heart of the final fuzzy system, will involve extensive interviews with police officers, highway maintenance workers, ADOT engineers and other personnel with knowledge of the important parameters and issues related to safe driving speeds on the highway chosen for deployment. As the fuzzy rules are developed, they will be entered into a fuzzy software development system in preparation for simulation testing. Part of this development process will involve defining the linguistic terms used to create the fuzzy rules as well as the actual parameter ranges associated with the various linguistic terms and input variables.

Simulation Testing (January 1997 - March 1997)

A software simulation of the fuzzy control system will be tested. These tests will be run in collaboration with police, highway maintenance personnel, ADOT engineers, and others familiar with highway safety issues.

Build and Test Prototype (April 1997 - June 1997)

A stand-alone prototype of the final variable speed limit device will be constructed and tested in a simulation environment. The same test data used for the software simulation will be used to test the prototype.

Completion of Final Report (June 1997 - July 1997)

A final report will be written which documents the information derived from the development of the fuzzy linguistic rules, the implementation of the fuzzy software and hardware test system, and the final results

Preliminary Cost Analysis - (approx. $92,000)

Release time covering two semesters for two NAU professors. $52,000

Two student assistants for two semesters $4000

Prototype control systems $10,000

One PC laptop - for transporting the fuzzy software simulation to personnel in various locations:	$2500
One fuzzy controller development system:	$2500
Miscellaneous hardware and software: (e.g. transducers, converters, software for simulation testing, etc.)	$5000

Travel. $6000
Working with personnel from ADOT, DPS, etc. in developing and testing the fuzzy control rules plus meetings with fuzzy system experts.

Final Report. $20,000
Two NAU professors for 6 man-weeks plus student support.

Future Directions

Implementation and Testing of System

If the outcome of the simulation testing of the fuzzy variable speed limit control system is deemed successful by the architects of the completed system as well as ADOT and the FHWA, the next step would be planning, funding and deploying an operational field test. Again those experts used in the initial development process would be used to evaluate the field test.

Performance Measures and Evaluation

The evaluation of the fuzzy variable speed limit control system would include at a minimum the following issues:

- determining if the technology enhances the transportation system
- determining whether the technology enhances existing ITS features already deployed in the field
- recommendation on whether to expand the project in the corridor or elsewhere
- demonstration of the benefits to the public and private sectors
- demonstration that the completed project meets corridor needs as identified in the Strategic Plan for Early Deployment of Intelligent Transportation Systems on Interstate 40 Corridor project for Arizona

Other Applications

The successful results from this project will put in place a technical foundation for solving other critical transportation problems. The successful design and implementation of a fuzzy variable speed limit device would open the way for many other applications of fuzzy logic to intelligent transportation systems. Among these applications would be intelligent traffic signal systems, intelligent in-vehicle communication systems, and intelligent dust-storm warning devices. Many other ITS systems could benefit from applications utilizing this technology.

ARIZONA DEPARTMENT OF TRANSPORTATION

Joint Project Administration

Progress Final Payment Report

Report No.	FA	Non FA	Exp. Budget Obj. Code	Contract No.

TRACS No.
Project No. Date Ending

Name of Project:

Name Of Consultant:

Date Started	Estimated Completion Date:	% Billed	% Complete

SUMMARY OF WORK FOR WHICH PAYMENT IS REQUESTED

Item	Description	Total Contract Amount	Previous Accumulative Amount	Current Month	Accumulative Amount

Submitted By: ______________________ Date__________
Consultant

Approved By: ______________________ Date__________
ADOT Project Monitor

Approved By: ______________________ Date__________
Joint Project Administration

Total To Date		
Total Previous Report		
Current Report		

CONMASTR/PRFORMAT

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3. The fuzzy system design process involves close interaction with experts in the problem domain. In the case of the development of an intelligent traffic system, those persons most qualified to assess the safety issues (i.e. the Arizona Department of Public Safety, highway maintenance personnel, ADOT engineers, etc.) would be intimately involved in the design effort.
4. Fuzzy control systems make use of linguistic rules that can be read and understood by engineers and non-engineers alike. The rules that form the heart of a fuzzy control system are written in everyday linguistic terms provided by the domain experts themselves. This allows these same experts not only to actively participate in the design process but also to participate in the review and testing process.

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Working with imprecision can actually be used to advantage when solving problems such as determining a safe driving speed based on subjective measurements. To understand this advantage consider the consequences of treating the wind velocity *brisk* as a precise category or set of values. First one would have to determine the exact range of velocities that are to be classified as brisk. If one decided that the low end of this range was 50 mph, then a wind velocity of 49.9999 mph would not be considered to be brisk whereas a wind velocity of 50.0000 mph would be considered a brisk velocity. Similarly if one decided that the high end of the set of brisk velocities was 75 mph, then a wind velocity of 75.0001 mph would not be considered to be brisk whereas a wind velocity of 75.0000 would be regarded as a brisk velocity. Both of these precise limits do not relate well to the way in which a category like *brisk* is used in everyday life. A small change in wind velocity should not result in a large and abrupt change in how the new velocity is conceptualized. Such an abrupt transition occurs only when brisk is assumed to be a precise concept because then any given wind velocity must be classified as belonging to the set *brisk* either completely or not at all. In other words, without imprecision the boundaries of categories are abrupt and precise.

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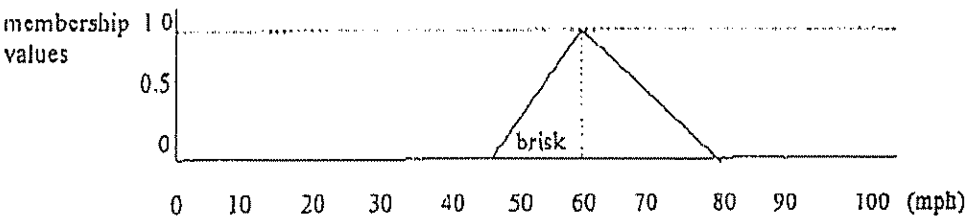
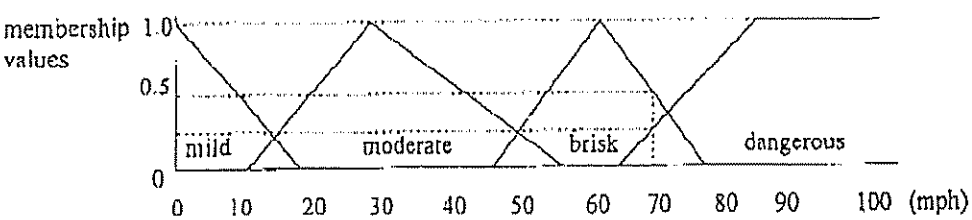


In the graph above, only the velocity 60 mph belongs completely to the set *brisk* since its membership value is 1.0. All other velocities roughly between 45 and 80 mph belong to the set with membership values somewhere between 0.0 and 1.0. For example, 55 mph has a membership value of approximately 0.7 in the set *brisk*. In other words, it can be said that 55 mph has the attribute of briskness to degree 0.7 whereas 60 mph has 100% of the attribute of briskness. When other categories of wind velocity are added to the graph above, it can be seen that making our sets fuzzy or imprecise allows wind velocities to belong to more than one set. For example, in the graph given below 70 mph belongs to the set of *brisk* velocities to about degree 0.5 and it also belongs to the set of *dangerous* velocities to roughly degree 0.25. Thus 70 mph is considered both a brisk and a dangerous velocity although it is more brisk than dangerous. This overlapping of conceptual categories is compatible with the way humans think about the world and it also results in control systems whose output characteristics move smoothly from one category of input value to the next.

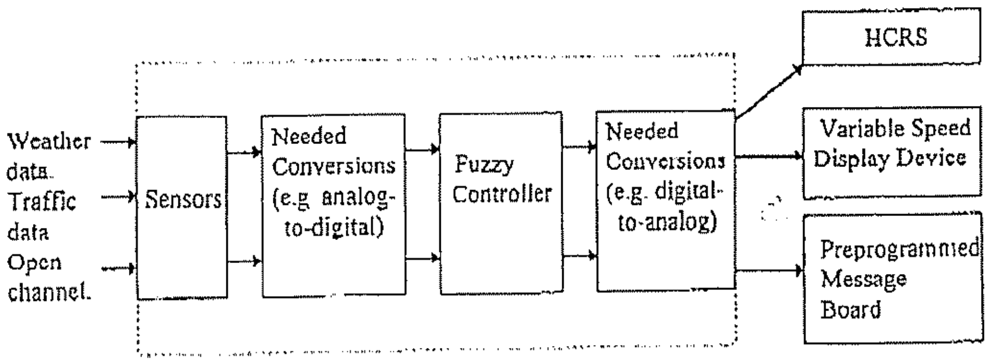


It is important to point out that the use of linguistic terms like *high*, *brisk*, and *low*, in a fuzzy system's rule set, allows that rule set to be read and understood by persons with and without extensive technical training. The rules offer an intuitive view of how the corresponding fuzzy control system operates. In fact this intuitive approach to modeling a control problem has many advantages. One major advantage relates to the development of the fuzzy control algorithm (rule set). A fuzzy system can be effectively developed by working closely with experts in a field of interest. The knowledge of these experts is directly encoded in a simple set of conditional statements that use linguistic terms and categories utilized by the experts themselves. The rules then reflect the manner in which the experts think and reason about their field of expertise. Even though these experts are not trained as fuzzy engineers, they can actively participate in the development of the fuzzy control algorithm that solves the problem of interest. In addition to this, they also can easily review the rules at each stage of development in order to eliminate inaccuracies or misunderstandings early in the design process.

The development of a fuzzy control algorithm for a variable speed limit device would involve close interaction with police officers, highway maintenance workers, ADOT engineers, and other related personnel. The experience and knowledge of these experts would be directly encoded into the fuzzy control system developed for the variable speed limit device. This same pool of experts would be used to review the rules developed in order to provide feedback on the overall conceptual fitness of the rule set. Of course, the final implementation and simulation testing of the system would be conducted by the engineers responsible for creating the system. However, the simulated system could be made available to the real "experts" so that they could also be involved in testing the system by comparing their intuitive notion of what the input-output relationships should be with the actual performance of the simulated system.

Design Concept

The fuzzy variable speed limit system being proposed would contain multiple inputs and at least two outputs. The inputs would be made up of various types of sensor data such as wind velocities, road ice thickness, road water levels and other weather related information. Other inputs might include traffic information such as traffic flow density data and traffic speed data. The output of the proposed fuzzy system would include a variable speed limit rating as well as a signal to be broadcast to a preprogrammed traffic message board. A simple block diagram is given below.



In the diagram above, an open channel has also been suggested. This channel could be used by police or ADOT to send a signal to the fuzzy controller. This signal might be used to override all other inputs in the case of an accident or other emergency situation.

Development Plan

Develop Fuzzy Algorithm (August 1997 - December 1997)

Development of the fuzzy control algorithm, the heart of the final fuzzy system, will involve extensive interviews with police officers, highway maintenance workers, ADOT engineers and other personnel with knowledge of the important parameters and issues related to safe driving speeds on the highway chosen for deployment. As the fuzzy rules are developed, they will be entered into a fuzzy software development system in preparation for simulation testing. Part of this development process will involve defining the linguistic terms used to create the fuzzy rules as well as the actual parameter ranges associated with the various linguistic terms and input variables.

Simulation Testing (January 1997 - March 1997)

A software simulation of the fuzzy control system will be tested. These tests will be run in collaboration with police, highway maintenance personnel, ADOT engineers, and others familiar with highway safety issues.

Build and Test Prototype (April 1997 - June 1997)

A stand-alone prototype of the final variable speed limit device will be constructed and tested in a simulation environment. The same test data used for the software simulation will be used to test the prototype.

Completion of Final Report (June 1997 - July 1997)

A final report will be written which documents the information derived from the development of the fuzzy linguistic rules, the implementation of the fuzzy software and hardware test system, and the final results

Preliminary Cost Analysis - (approx. $92,000)

Release time covering two semesters for two NAU professors. $52,000

Two student assistants for two semesters $4000

Prototype control systems $10,000

One PC laptop - for transporting the fuzzy software simulation to personnel in various locations:	$2500
One fuzzy controller development system:	$2500
Miscellaneous hardware and software: (e.g. transducers, converters, software for simulation testing, etc.)	$5000

Travel. $6000

Working with personnel from ADOT, DPS, etc. in developing and testing the fuzzy control rules plus meetings with fuzzy system experts.

Final Report. $20,000

Two NAU professors for 6 man-weeks plus student support.

Future Directions

Implementation and Testing of System

If the outcome of the simulation testing of the fuzzy variable speed limit control system is deemed successful by the architects of the completed system as well as ADOT and the FHWA, the next step would be planning, funding and deploying an operational field test. Again those experts used in the initial development process would be used to evaluate the field test.

Performance Measures and Evaluation

The evaluation of the fuzzy variable speed limit control system would include at a minimum the following issues:

- determining if the technology enhances the transportation system
- determining whether the technology enhances existing ITS features already deployed in the field
- recommendation on whether to expand the project in the corridor or elsewhere
- demonstration of the benefits to the public and private sectors
- demonstration that the completed project meets corridor needs as identified in the Strategic Plan for Early Deployment of Intelligent Transportation Systems on Interstate 40 Corridor project for Arizona

Other Applications

The successful results from this project will put in place a technical foundation for solving other critical transportation problems. The successful design and implementation of a fuzzy variable speed limit device would open the way for many other applications of fuzzy logic to intelligent transportation systems. Among these applications would be intelligent traffic signal systems, intelligent in-vehicle communication systems, and intelligent dust-storm warning devices. Many other ITS systems could benefit from applications utilizing this technology.

ARIZONA DEPARTMENT OF TRANSPORTATION
Joint Project Administration

Progress		Final		Payment Report
Report No.	FA	Non FA	Exp. Budget Obj. Code	Contract No.

TRACS No.
Project No. Date Ending

Name of Project:

Name Of Consultant:

Date Started	Estimated Completion Date:		% Billed	% Complete

SUMMARY OF WORK FOR WHICH PAYMENT IS REQUESTED

Item	Description	Total Contract Amount	Previous Accumulative Amount	Current Month	Accumulative Amount

Submitted By: ______________________ Date__________
Consultant

Approved By: ______________________ Date__________
ADOT Project Monitor

Approved By: ______________________ Date__________
Joint Project Administration

Total To Date		
Total Previous Report		
Current Report		

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